DOWN ON THE FARM

NANOTECHNOLOGY IN THE FOOD CHAIN

Corporations worldwide are engaged in nanotechnology research to put nanoparticles into the food we eat, the cosmetics we use and the packaging that contains them.

Part 2 of 2

by ETC Group
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NANO-FOOD AND NUTRITION, OR "NANOTECH FOR TUMMIES"

A handful of food and nutrition products containing invisible nano-scale additives are already commercially available. Hundreds of companies are conducting research and development (R&D) on the use of nanotech to engineer, process, package and deliver food and nutrients to our shopping baskets and our plates. Among them are giant food and beverage corporations as well as tiny nanotech start-ups.

According to Jozef Kokini, the director of the Center for Advanced Food Technology at Rutgers University (New Jersey, USA), "every major food corporation has a program in nanotech or is looking to develop one".[153] A 2004 report produced by Helmut Kaiser Consultancy, "Nanotechnology in Food and Food Processing Industry Worldwide", predicts that the nano-food market will surge from US$2.6 billion today to $7 billion in 2006 and to $20.4 billion in 2010.[154] In addition to a handful of "nano-food" products that are already on the market, over 135 applications of nanotechnology in food industries (primarily nutrition and cosmetics) are in various stages of development.[155]

According to Helmut Kaiser, more than 200 companies worldwide are engaged in nanotech R&D related to food. Among the 20 most active companies are five that rank among the world's 10 largest food and beverage corporations, Australia's leading food corporation and Japan's largest seafood producer and processed food manufacturer. (See annex 1.)

Despite the obvious enthusiasm for nano-scale science and its applications to food engineering and processing, the food and beverage industry is generally conservative and cautious when talking about the future of nanotech and food. Most industry representatives interviewed by ETC Group declined to provide specific details about the level of funding and industry partners. We spoke to scientists at giant food and beverage corporations (Kraft and Nestlé) as well as university researchers and representatives from small nanotech start-ups (often one and the same).

After witnessing widespread rejection of genetically modified foods, the food industry may be especially skittish about owning up to R&D on "atomically modified" food products. "The food industry is more traditional than other sectors like IBM [where nanotechnology can be applied]," explains Gustavo Larsen, a professor of chemical engineering and a former consultant to Kraft.[156] "My take is that there are good opportunities and it's often more feasible to realise these opportunities [in the food sector]. You can make nanoparticles and use them in foods—you don't have to assemble them first."[157] When asked what he believes will be the first products of nanotech R&D related to food, Larsen said that consumers are likely to see packaging composed of nano-scale materials before novel food products. "I think the packaging is a safer bet," said Larsen.

Molecular Food Manufacturing

Some people claim that in the future, molecular engineering will enable us to "grow" unlimited quantities of food without soil, seed, farms or farmers—and that it will wipe out global hunger in the process. Consider the following views:

• "Nanomachines could create unlimited amounts of food by synthesis at the atomic level, which would eradicate hunger." – Carmen I. Moraru, professor of food science, Cornell University (USA), on nanotech's potential impact on food science[158]

• "Molecular biosynthesis and robotic replenishment may allow quick replacement of production, so we wouldn't have to depend on centralized systems to grow and deliver our food. In the first, primitive stages of molecular assembly, we'd build packaged greenhouses, radically different from those today, that would allow local or individualized production by millions who know nothing about farming... At the next stage of molecular manufacturing, food synthesis could occur directly, without growing crops or livestock." – Douglas Mulhall, *Our Molecular Future* (Prometheus Books, 2002)

• "Why can't human beings imitate nature's methodology? Instead of harvesting grain and cattle for carbohydrates and protein, nanomachines (nanobots) could assemble the desired steak or flour from carbon, hydrogen, and oxygen atoms present in the air as water and carbon dioxide. Nanobots present in foods could circulate through the blood system, cleaning out fat deposits and killing pathogens." – Dr Marvin J. Rudolph, director, DuPont Food Industry Solutions, in *Food Technology*, January 2004

Producing food by molecular manufacturing[159] is the most ambitious goal of nanotech—and the least likely to materialise any time soon. To those who have followed the biotech debate over the past two decades, enthusiastic claims that a new technology will feed hungry people is a tired and empty refrain. Nano-optimists see the future through the biotech industry's rose- (and green-) coloured glasses: now it's nanotech, they claim, that will eradicate hunger by increasing agricultural yields, enhancing the nutritional content of food and eliminating the risk of food allergens.[160]

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ETC Group concludes that present-day "nanotech for tummies" is following the same trajectory as other nano-scale R&D, with the earliest applications in the area of "smart" materials and sensors. More revolutionary applications, such as the atomic modification of food, are perhaps more distant. But it's worth noting that a few ambitious scientists are trying to create food in the lab.

Tissue engineers at Touro College (New York City) and at the Medical University of South Carolina (USA) are experimenting with growing meat by "marinating" fish myoblast (muscle) cells in liquid nutrients to encourage the cells to divide and multiply on their own. The first goal is to keep astronauts in space from going hungry.[161]

"Here, take one of our promotional DVDs."

Packaging

Today, food packaging and monitoring are a major focus of food industry related nanotech R&D. Packaging that incorporates nanomaterials can be "smart", which means that it can respond to environmental conditions or repair itself or alert a consumer to contamination and/or the presence of pathogens.

According to industry analysts, the current US market for "active, controlled and smart" packaging for foods and beverages is an estimated $38 billion—and will surpass $54 billion by 2008.[167]

The following examples illustrate nano-scale applications for food and beverage packaging:

• Chemical giant Bayer produces a transparent plastic film (called Durethan) containing nanoparticles of clay. The nanoparticles are dispersed throughout the plastic and are able to block oxygen, carbon dioxide and moisture from reaching fresh meats or other foods.[168] The nanoclay also makes the plastic lighter, stronger and more heat-resistant.

• Until recently, industry's quest to package beer in plastic bottles (for cheaper transport) was unsuccessful because of spoilage and flavour problems. Today, Nanocor, a subsidiary of Amcol International Corp., is producing nanocomposites for use in plastic beer bottles that give the brew a six-month shelf life.[169] By embedding nanocrystals in plastic, researchers have created a molecular barrier that helps prevent the escape of oxygen. Nanocor and Southern Clay Products are now working on a plastic beer bottle that may increase shelf life to 18 months.[170]

• Kodak, best known for producing camera film, is using nanotech to develop antimicrobial packaging for food products that will be commercially available in 2005. Kodak is also developing other "active packaging" which absorbs oxygen, thereby keeping food fresh.[171]

• Scientists at Kraft as well as at Rutgers University and the University of Connecticut are working on nanoparticle films and other packaging with embedded sensors that will detect food pathogens. Called "electronic tongue" technology, the sensors can detect substances in parts per trillion and would trigger a colour change in the packaging to alert the consumer if a food has become contaminated or if it has begun to spoil.[172]

• Researchers in The Netherlands are going one step further to develop intelligent packaging that will release a preservative if the food within begins to spoil. This "release on command" preservative packaging is operated by means of a bioswitch developed through nanotechnology.[173]

• Developing small sensors to detect food-borne pathogens will not just extend the reach of industrial agriculture and large-scale food processing. In the view of the US military, it's a national security priority.[174] With present technologies, testing for microbial food contamination takes two to seven days and the sensors that have been developed to date are too big to be transported easily.[175]

Several groups of researchers in the US are developing biosensors that can detect pathogens quickly and easily, reasoning that "super-sensors" would play a crucial role in the event of a terrorist attack on the food supply. With US Department of Agriculture (USDA) and National Science Foundation (NSF) funding, researchers at Purdue University are working to produce a hand-held sensor capable of detecting specific bacteria instantaneously from any sample. They've created a start-up company called BioVitesse.[176]

While devices capable of detecting food-borne pathogens could be useful in monitoring the food supply, sensors and smart packaging will not address the root problems inherent in industrial food production that result in contaminated foods: faster meat (dis)assembly lines, increased mechanisation, a shrinking labour force of low-wage workers, fewer inspectors, the lack of corporate and government accountability and the great distances between food producers, processors and consumers.

Just as it has become the consumer's responsibility to make sure meat has been cooked long enough to ensure that pathogens have been killed, consumers will soon be expected to act as their own meat inspectors so that industry can continue to trim safety overhead costs and increase profits.

A "nanobarcode" is an alternative tagging or monitoring device that works more like a barcode, but on the nano-scale.

Tagging and Monitoring:
• Radio Frequency ID (RFid) Tags

An RFid tag is a small, wireless, integrated circuit (IC) chip with a radio circuit and an identification code embedded in it. The advantages of the RFid tag over other scannable tags—such as the UPC barcodes pasted on most consumer products today—are that the RFid tag is small enough to be embedded in the product itself, not just on its package, it can hold much more information, can be scanned at a distance (and through materials, such as boxes or other packaging) and many tags can be scanned at the same time.

RFid tags are already being used for livestock tracking, attached to the ear or injected into the animal. The entire chip can be about the size of a dust mote—closer to micro-scale than nano-scale, though incorporating nano-scale components. Developers of the technology envision a world where they can "identify any object anywhere automatically".[177]

RFid tags could be used on food packaging to perform relatively straightforward tasks, such as allowing cashiers in supermarkets to tally all of a customer's purchases at once or alerting consumers if products have reached their expiration dates. RFid tags are controversial because they can transmit information even after a product leaves the supermarket.

Privacy advocates are concerned that marketers will have even greater access to data on consumer behaviour. They want the tags to be disabled at the cash register (what is known as "tag killing") to ensure that personal data won't be obtained and stored. Wal-Mart in the US and Tesco in the UK have already tested RFid tagging on some products in some stores.[178]

• Nanobarcodes

A "nanobarcode" is an alternative tagging or monitoring device that works more like the UPC code, but on the nano-scale. One type of nanobarcode—developed by Nanoplex Technologies—is a nanoparticle consisting of metallic stripes, where variations in the striping provide the method of encoding information.[179]

Nanoplex changes the length and width of the particles and the number, width and composition of each stripe to make billions and billions of variations. So far they've put barcodes into ink, fabric, clothing, paper, explosives and on jewellery. The codes can be read using a hand-held optical reader or a microscope that measures the difference in reflectivity of the metallic stripes. Silver and gold reflect light in different ways, for example, and it is the patterns of reflection that give each particle its unique code. In addition to gold and silver, Nanoplex makes codes out of platinum, palladium, nickel and cobalt.

Nanoplex also produces "Senser" (Silicon Enhanced Nanoparticles for Surface Enhanced Raman Scattering) tags—50-nanometre metal nanoparticles that exhibit unique codes similar to nanobarcodes. Senser tags can also be incorporated into packaging and read by an automated reader up to a metre away, allowing items to be read at a checkout like RFID tags or covertly at ports.[180]

The tagging of food packages will mean that food can be monitored from farm to fork—during processing, while in transit, in restaurants or on supermarket shelves and, eventually, even after the consumer buys it. Coupled with nanosensors, those same packages can be monitored for pathogens, temperature changes, leakages, etcetera.

Nano-food: What's Cooking?[181]

In 1999, Kraft Foods, the $34 billion Altria (formerly known as Philip-Morris) subsidiary, established the industry's first nanotechnology food laboratory. The next year, Kraft launched the NanoteK consortium, enveloping 15 universities and public research labs from around the globe.[182] None of the scientists involved in the consortium is a food scientist by training; rather, they're a mix of molecular chemists, material scientists, engineers and physicists.[183]

Looking at food from an engineering perspective is nothing new. For the last three decades, scientists have introduced genes from one species of plant or animal into another using genetic modification (GM) technologies; but at least for a thousand years before that, people introduced specially formulated additives to food to impart new flavours, textures, colours or other qualities.

Nano-scale technologies will take food engineering "down" to a new level, with the potential to change dramatically the way food is produced, grown, processed, packaged, transported and even eaten.

• Nano-scale food additives

In fact, the products of nanotechnology have already begun to "appear" in food (though they are too small to be seen—and consumers would have no way of knowing, since there is no requirement for labelling and no size-specific regulation).

BASF, for example, produces a nano-scale version of carotenoids, a class of food additives that imparts an orange colour and that occurs naturally in carrots and tomatoes. Some types of carotenoids are antioxidants and can be converted to vitamin A in the body. BASF sells its nano-scale synthetic carotenoids to major food and beverage companies worldwide for use in lemonades, fruit juices and margarines.[184] Nano-scale formulation makes them more easily absorbed by the body but also increases shelf life. BASF's carotenoid sales are US$210 million annually. This figure includes both nano-scale and other carotenoids.[185]

In 2002, BASF submitted a GRAS (Generally Recognized as Safe) notice to inform the FDA of its sale of a synthetic carotenoid called lycopene (which occurs naturally in tomatoes) as a food additive. BASF's synthetic lycopene is formulated at the nano-scale.[186] According to BASF, the question of specialised testing for nanoparticulated lycopene was not raised and was not required because "BASF demonstrated safety in a variety of...toxicological evaluations".[187] The FDA accepted BASF's notice without question.[188]

In a telephone interview, Robert Martin of the FDA confirmed that size was not taken into account in the review of BASF's synthetic lycopene, and he explained further that "size *per se*" is "not a major consideration" in regulatory review but would be addressed "on a case-by-case basis" if there appeared to be implications for health and safety.[189]

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Is it safe to add nanoparticles to foods? The short answer to the question is, "No one knows for sure". The issue has yet to be confronted head on by either regulators or the scientific community.

ETC Group has identified only a handful of nano-scale food additives on the market today, but we can't be certain how widespread their use is since there are no requirements that they be labelled as such. Just as in other regulatory arenas such as cosmetics and chemicals, the question of safety has not been approached from the perspective of size. So far, manufacturers have been the only ones to consider size—primarily in terms of the market advantages that extremely small size offers (e.g., a decrease in size increases bioavailability in foods and increases transparency in cosmetics).

In the case of additives that also occur naturally in foods, it is not clear what the nano-specific safety issues are. Discussing nano-scale lycopene, for example, Dr Gerhard Gans of BASF explained that once the synthetic, nano-scale lycopene reaches the gut, it behaves in exactly the same way the lycopene in a tomato behaves: it is broken down by digestive enzymes and taken into the bloodstream and further to the liver and other organs as individual molecules.[190] In other words, by the time it enters the bloodstream, all food is nano-scale—whether it started out as a slice of tomato or a glass of lemonade containing BASF's synthetic lycopene. (Perhaps because of health concerns related to nanoparticles, Dr Gans emphasised that the synthetic lycopene handled by BASF employees and supplied to their customers was not in the form of nanoparticles; at that stage, he said, the particles have clumped together in aggregates of micron-level size, which will partially dissolve in the final product. Ultimately, the consumer's digestive enzymes bring the particles back down to the nano-scale.)

While the explanation that all food is nano-scale by the time it reaches the bloodstream makes sense *a priori*, it is important to note that BASF conducted toxicological testing of its lycopene not because it was a nano-scale formulation but because it was produced through chemical synthesis (rather than derived from lycopene-containing fruits and vegetables). Had synthetic lycopene already been vetted as a food ingredient, BASF would not have been compelled by regulators to test the safety of a nano-scale version.

This is what makes the prospect of adding nanoparticles to foods—in the absence of specific regulatory attention paid to size—alarming: what nano-scale substances are in the pipeline that have already been approved as food additives at larger scales but may now be formulated at the nano-scale with altered properties and unknown consequences? Of particular concern would be nano-scale formulations of substances that do not already occur naturally in food.

• Titanium Dioxide and Silicon Dioxide Coatings

Take titanium dioxide (TiO_2) as an example: TiO_2 was approved as a food colour additive by the US FDA in 1966, with the only stipulation being "not to exceed 1% by weight".[191] (Micron-sized TiO_2 imparts a bright white colour and is added to icings on cookies and cakes). The FDA has also approved TiO_2 as a "food contact substance"—meaning that if it comes into contact with food when it is incorporated into packaging, it won't cause harm. TiO_2 has been used as a colourant (white) in paper used for food packaging.[192]

With advances in nanotech techniques, TiO_2 can now be formulated at the nano-scale. The quantum property changes that take place with the reduction in size offer advantages for certain applications. But some of nano-scale TiO_2's property changes—such as increased chemical reactivity—have caused concern in applications where the nano-scale substance comes into intimate contact with the human body, (e.g., as an ingredient in cosmetics).[193] Nano-scale TiO_2 particles are no longer white (they are transparent), but they still block ultraviolet (UV) light in the way their larger siblings do. Transparent, nano-scale TiO_2 is now being used in clear plastic food wraps for UV protection.

Because TiO_2 has already been approved as a food colour additive and as a food contact substance, its nano-scale use in foods does not require additional toxicity testing. And the per-cent-by-weight limits set back in the 1960s aren't necessarily relevant to today's nano-scale formulations, since tiny amounts can produce large effects.

Silicon dioxide (SiO_2), also known as silica, is another example of an FDA-approved food additive that doesn't occur naturally in foods. Silica is a common substance in nature—beach sand and quartz are almost-pure forms of crystalline silica.[194]

In addition to a crystalline form, silica occurs naturally in an amorphous form, e.g., diatomaceous earth, and it is this form of silica that is produced synthetically and is an FDA-approved food ingredient as an anti-caking agent.[195] (Amorphous silica is also known as "fumed" silica.) The regulation states that the silica content must be less than two per cent of the weight of the food. Food-grade fumed silica with particle sizes in the nanometre range are commercially available.[196] Again, it is not clear what food products contain synthetic nano-scale silica as there are no labelling requirements.

Mars, Inc., one of the world's largest private food corporations, was issued US Patent No. 5,741,505 in 1998 on "edible products having inorganic coatings". The coatings create a barrier to prevent oxygen or moisture from reaching the product under the coating, thereby increasing shelf life.

The patent claims the invention will keep hard candy from getting sticky, cookies from getting stale, cereals from becoming soggy in milk, etc. The coatings can be made from various chemical compounds, of which SiO_2 and TiO_2 are specifically mentioned. According to the inventors, the coating should be extremely thin because of regulatory requirements and because of texture and "mouth feel" considerations.

The patent states that the ideal coating would be somewhere between 0.5 nm and 20 nm thick. While the coating could be made of any inorganic material, the inventors state that it is preferable to use a substance that has already been GRAS-certified by the FDA, such as SiO_2 and TiO_2. The patent application describes an example of their invention, in which they coated M&Ms, Twix and Skittles brand candies with an inorganic nanofilm.

ETC Group is not in the position to assess the safety of nano-scale food additives. We want to highlight the regulatory vacuum, where size does not matter and nano-scale formulations do not trigger any special regulatory scrutiny. It's a kind of "particle nepotism" that could have dangerous consequences: if Big Brother passes the safety test, Little Brother doesn't even have to take the exam.

Like the pharmaceutical, agrochemical and cosmetics giants, food and beverage companies are also experimenting with the use of nanocapsules to deliver active ingredients.

Special Delivery

The food industry aims to engineer food so that it is more "functional"—meaning more nutritious (or perceived to be) or serving some other purpose beyond its biological purpose of providing energy through calorie consumption.

Many companies believe that nano-scale technologies will help in this quest, and so they are focusing on "delivery". Most of us don't think very much about delivery when it comes to food (unless we're waiting for a pizza to arrive from across town): we bite, chew, swallow and our digestive tracts take care of the rest. But in order to benefit from delivery—whether it's the vitamin C from an apple we've just bitten into or the synthetic lycopene in our lemonade—the nutrient must go to the right place in the body and it must be active when it gets there.[197]

Controlling and engineering nutrient delivery is a challenge, and its mastery will be enormously profitable. According to industry analysts, in the US alone the market for functional foods containing medically beneficial nutrients—worth $23 billion in 2003—will exceed $40 billion in 2008.[198]

In December 2000, ETC Group reported on the biotech industry's quest to develop a new generation of biotech products, genetically modified "nutraceuticals" and functional foods that seek to deliver clear (or at least perceived) consumer benefits.[199] Tainted by the wider controversy over GM crops, however, the GM nutraceutical products have been largely stuck in the pipeline. Will nanotech deliver where biotech has failed?

Like the pharmaceutical, agrochemical and cosmetics giants, food and beverage companies are also experimenting with the use of nanocapsules to deliver active ingredients. One way to preserve an active component is by putting it in a protective "envelope". The envelope can be engineered to dissolve, or the active ingredient can be made to diffuse through the envelope triggered by the right stimulus.

There are already several hundred types of "microcapsules" being used as food additives in the US alone,[200] some to achieve the controlled release of active ingredients. George Weston Foods of Australia, for example, sells a version of its popular Tip Top bread, known as "Tip Top-up", which contains microcapsules of tuna fish oil high in omega-3 fatty acids. Because the tuna oil is contained in a microcapsule, the consumer doesn't taste the fish oil, which is released in digestion once it has reached the stomach. The same technology is also being employed in yoghurts and baby foods. Companies large (Unilever, Kraft) and small (see below) are now developing "nanocapsules":

• Researchers at Hebrew University in Jerusalem have created a start-up company called Nutralease. They've applied for a patent[201] on a nano-scale self-assembled structure that can carry active components into and through the human body. According to the company's patent application, their "nanovehicle" can be diluted in either oil or water without affecting its active ingredient. The company's nanovehicles are already on the market in a cholesterol-reducing canola oil.[202] Nutralease has just signed a deal with an Israeli meat company that wants to inject a little health into its hot dogs, and another deal with an ice cream manufacturer is in the works.[203]

• Royal BodyCare, a company based in Texas (USA), has created what it calls "nanoceuticals" (and has applied for a trademark on the name) using a different kind of envelope to deliver "powerful, tiny mineral clusters that are believed to increase the absorption of nutrients into our cells".[204] Royal BodyCare puts these nanoceutical particles into its line of "SuperFoods" nutritional supplements.

• BioDelivery Sciences International (BDSI) has developed and patented "nanocochleates"—coiled nano-scale particles (as small as 50 nm in diameter) derived from soy (not genetically modified, they emphasise!) and calcium that can carry and deliver pharmaceutical compounds as well as nutrients such as vitamins, lycopenes and omega fatty acids directly to cells. The company claims that its nanocochleates can deliver omega-3 fatty acids to cakes, muffins, pasta, soups and cookies without altering the product's taste or odour.[205] No products containing the nanocochleate delivery system are currently on the market, but the company actively seeks to license its technology.

"We have some [food] companies that are clearly enthusiastic," said Raphael Mannino, chief scientific officer of BDSI.[206] Mannino told ETC Group that it is not yet clear what regulatory hurdles his company's nano-scale nutrient delivery system would need to clear before commercialisation. "Nobody is really sure yet," said Mannino.[207] Before it becomes a commercial reality, BDSI must achieve large-scale manufacture of the nanoencochleation technology. Under the most optimistic scenario, Mannino said that "we could be in food in one year".

• With funding from the USDA, LNK Chemsolutions is developing nano-scale capsules of edible polymers to prevent the flavour and aroma of food molecules from degrading. The goal is to increase the shelf life of sensitive food products, but the company declines to reveal which ones.[208] LNK Chemsolutions was founded by Dr Gustavo Larsen, a professor of chemical engineering at the University of Nebraska.

• Other companies are working on using nano-scale technologies to create "interactive foods" that operate using "on-demand" delivery. The idea is that the consumer will be able to choose—based on her individual aesthetics, nutritional needs or flavour preferences of the moment—which components will be activated and then delivered and which won't be.

Kraft's NanoteK consortium scientists are developing nanocapsules whose walls burst at different microwave frequencies so the consumer can "switch on" new tastes or colours. Countless nanocapsules would remain dormant and only the desired ones would be called into action. Kraft is also working on sensors that will be able to detect an individual's nutritional deficiencies and then respond with smart foods that release molecules of the needed nutrients.[209]

Eating is just one way to deliver active ingredients. Paris-based L'Oréal, the world's leading cosmetics firm, already markets skin care products containing nano-scale particles.

Early next year, food scientists will meet to discuss nano-scale and micro-scale approaches for controlled release and nutrient absorption in foods—at the first International Symposium on the "Delivery of Functionality in Complex Food Systems: Physically Inspired Approaches from Nano-scale to Micro-scale", at the Nestlé Research Centre in Lausanne, Switzerland.[210]

In addition to aiding nutrient delivery, nanoparticles may be used in foods to alter other properties. For example, margarine, ice cream, butter and mayonnaise all belong to a class of foods known as "colloids", where small particles are dispersed in some other medium—liquid, gas or solid. Unilever, Nestlé and others are conducting research and already hold patents on new ways to make colloids using nanoparticles that will extend shelf life, prolong flavour sensation in the mouth, alter texture and improve stability. (See annex 2.)

• Nutricosmetics

Eating is just one way to deliver active ingredients. Paris-based L'Oréal, the world's leading cosmetics firm, already markets skin care products containing nano-scale particles.[211] (Nestlé holds a 49% stake in L'Oréal.[212]) The company's "nanosomes" are tiny intercellular delivery systems that penetrate the skin and then release vitamin E. According to L'Oréal: "Given that the interstices of the outer layer of skin measure about 100 nanometres, nanovectors offer the best solution to the problem of transporting and concentrating active ingredients in the skin."[213]

Cosmetics containing invisible nanoparticles have not escaped notice in recent European reports on potential risks associated with manufactured nanoparticles. A Royal Society (UK) report released in July 2004 notes the dearth of toxicological data on manufactured nanoparticles.[214] Because these are used in some cosmetics and sunscreens, the report recommends that further studies be done into skin penetration by manufactured nanoparticles and that toxicological studies conducted by industry be placed in the public domain—no doubt causing some wrinkles for L'Oréal.

Food and cosmetics companies are now collaborating to develop "cosmetic nutritional supplements". L'Oréal and Nestlé recently formed Laboratoires Innéov, a 50/50 joint venture. Innéov's first product, called "Innéov Firmness", contains lycopene. The supplement is taken orally and is marketed to women over forty who are concerned about lost skin elasticity.[64]

Shortly after Nestlé cemented its collaboration with L'Oréal, Procter & Gamble and Olay announced they would be creating two lines of nutritional supplements together—one for "Beauty" and one for "Wellness".[216]

While these particular supplements are not advertised as using nano-scale technologies, it is difficult to be sure since there are no labelling requirements. In any case, the food and cosmetic alliances illustrate the tendency to blur boundaries between food, medicine and cosmetics, a trend that nanotech will likely accelerate. ∞

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ETC Group (formerly RAFI) is an action group on erosion, technology and concentration. Publications, including the full text, recommendations and annexes of *Down on the Farm: The Impact of Nano-scale Technologies on Food and Agriculture*, can be downloaded free of charge from the website, http://www.etcgroup.org, and are available in hardcopy from: ETC Group, 431 Gilmour Street, Second Floor, Ottawa, ON, Canada K2P 0R5, telephone +1 (613) 241 2267, fax +1 (613) 241 2506, email etc@etcgroup.org.

Editor's Note:
Due to a lack of space, we have not published the relevant and extensive footnotes. Instead, we encourage readers to obtain a copy of the full report from http://www.etcgroup.org and use it to generate debate within the community.